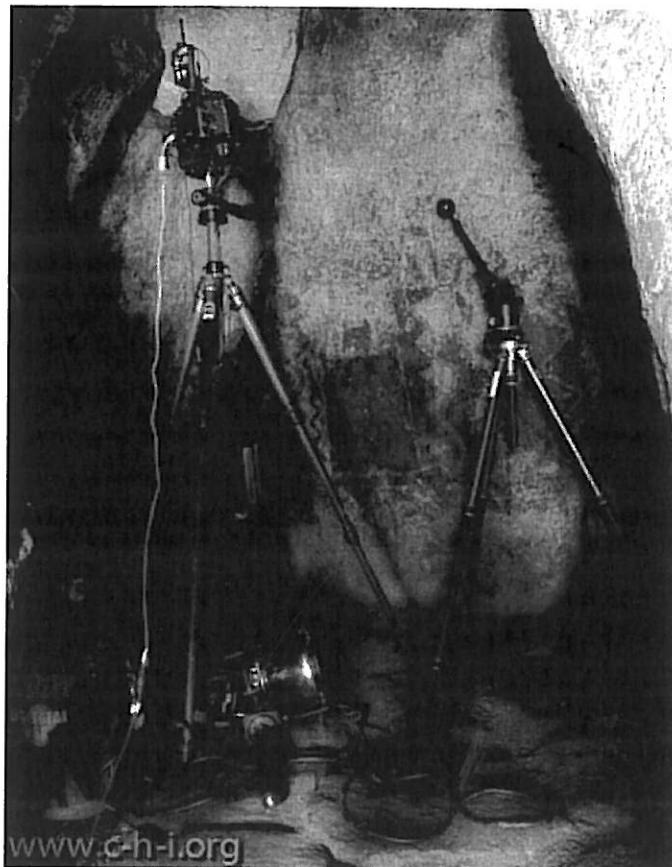


# REFLECTANCE TRANSFORMATION IMAGING: GUIDE TO HIGHLIGHT IMAGE CAPTURE

Document version 1.1

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*Reflectance Transformation Imaging: Guide to Highlight Image Capture* v1.1  
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# Setting up for Highlight RTI Image Capture

## Overview

Highlight RTI image capture is a technique for obtaining the original digital image data from which you can produce reflectance transformation images (RTIs). An RTI, in addition to storing the color data for each pixel, stores a *normal* value for each pixel that records its surface shape. The processing software calculates this value using data about the angle between the light source and the object.

In highlight RTI image-capture technique, you include an image of one or (preferably) two reflective spheres in each shot. The reflection of the light source on the spheres enables the processing software to calculate the lighting angle for that image. This allows you great flexibility in subject size and location.

## Physical setup summary

It is very important that the camera, the target object, and the reflective spheres do not move at all during the capture sequence; only the light moves.

You need to set up the following elements:

### ► Camera

You must set the digital camera on a tripod for stability, and to eliminate vibration during image capture. You might need to set the camera on a focusing slider for fine focus on small subjects. Sandbags or other weights help you to further stabilize the tripod.

We use Canon digital SLRs for illustration and demonstration, but many different camera types have produced high quality RTIs. You must be able to set exposure and aperture manually, and turn off auto-focus in order to keep a fixed focus on the subject.

You connect the camera to the computer, and use the computer to control it for testing your setup, and when shooting the images. You can trigger the camera and flash directly from the computer, or a remote trigger with a timer, like those used to shoot time-lapse sequences.

For details, see [“Camera setup” on page 5](#).

### ► Target object with reflecting spheres

Depending on the size and portability of the target object, you must compose the camera’s field of view so it can encompass both the object and two reflecting spheres of an appropriate size. The spheres must have a diameter of at least 200 pixels in the resulting photograph.

There are various ways to mount the reflecting spheres. In general, you can set the spheres on stands in the target area, or mount them on light stands or tripods to get them into the desired positions.

For details, see [“Subject and reflective sphere setup” on page 10](#).

### ► Lighting

You must have a portable lighting unit of a type and intensity appropriate to the location and environmental conditions. For this technique, you can attach the lighting unit to a pole or monopod,

and move it by hand into the general positions required for a complete set of images, in an imaginary hemisphere around the subject.

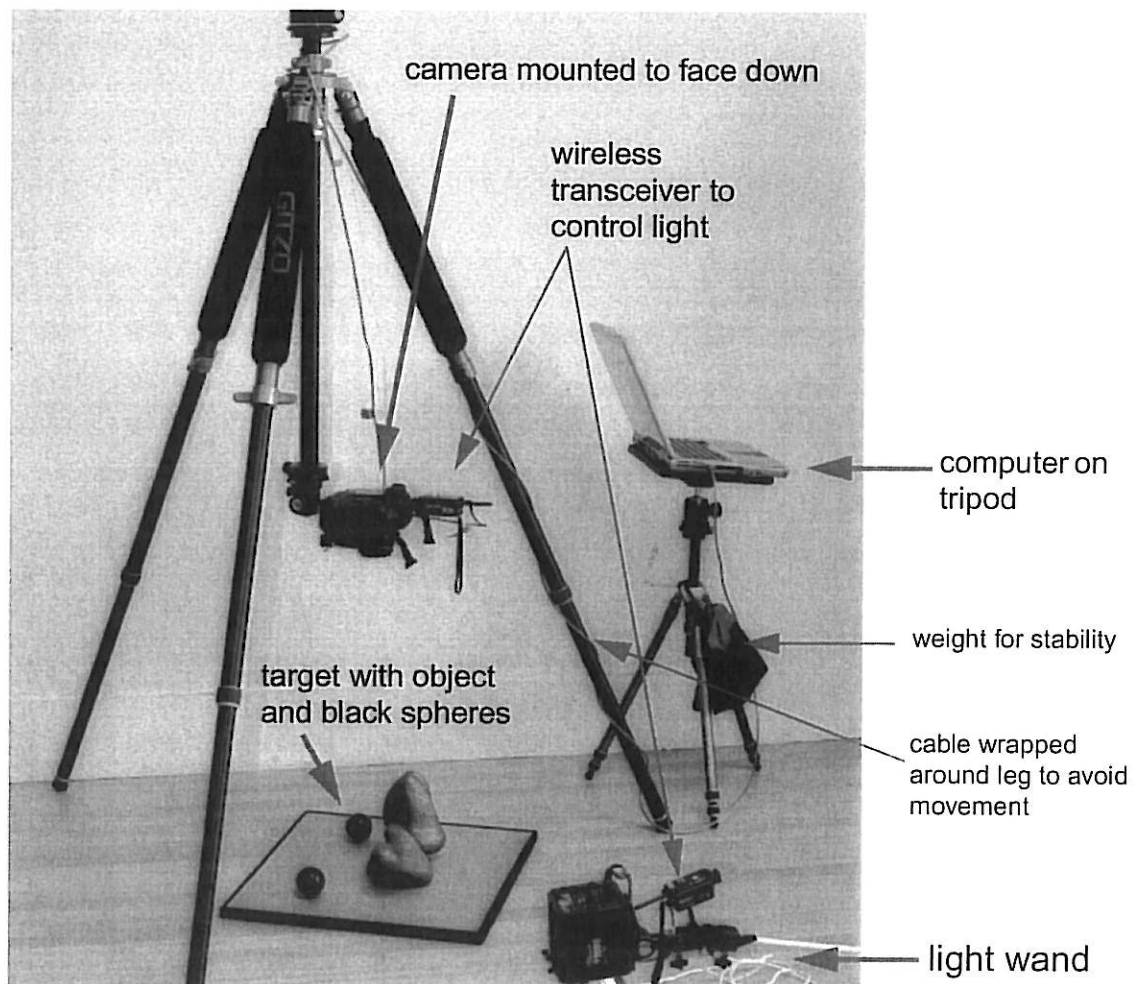
The distance of the light from the object must be nearly the same from all shots; you can easily measure it with a string.

For details, see ["Lighting setup" on page 15](#).

► Computer

The computer that controls the camera must be near enough to connect and be easily accessible, but must be placed out of the way of the object, camera, and lighting area. You can mount it on any stable surface. In outdoor field situations, it is useful to mount it on another tripod stabilized by weights or sandbags.

Connect the camera to the computer through a USB cable, as shown in ["Camera setup" on page 5](#), and install the camera-control application for your camera; see ["Computer software setup" on page 19](#). You must also install the capture and post-processing software that we provide, and the viewer application that allows you to view your RTI images. See ["Computer software setup" on page 19](#).



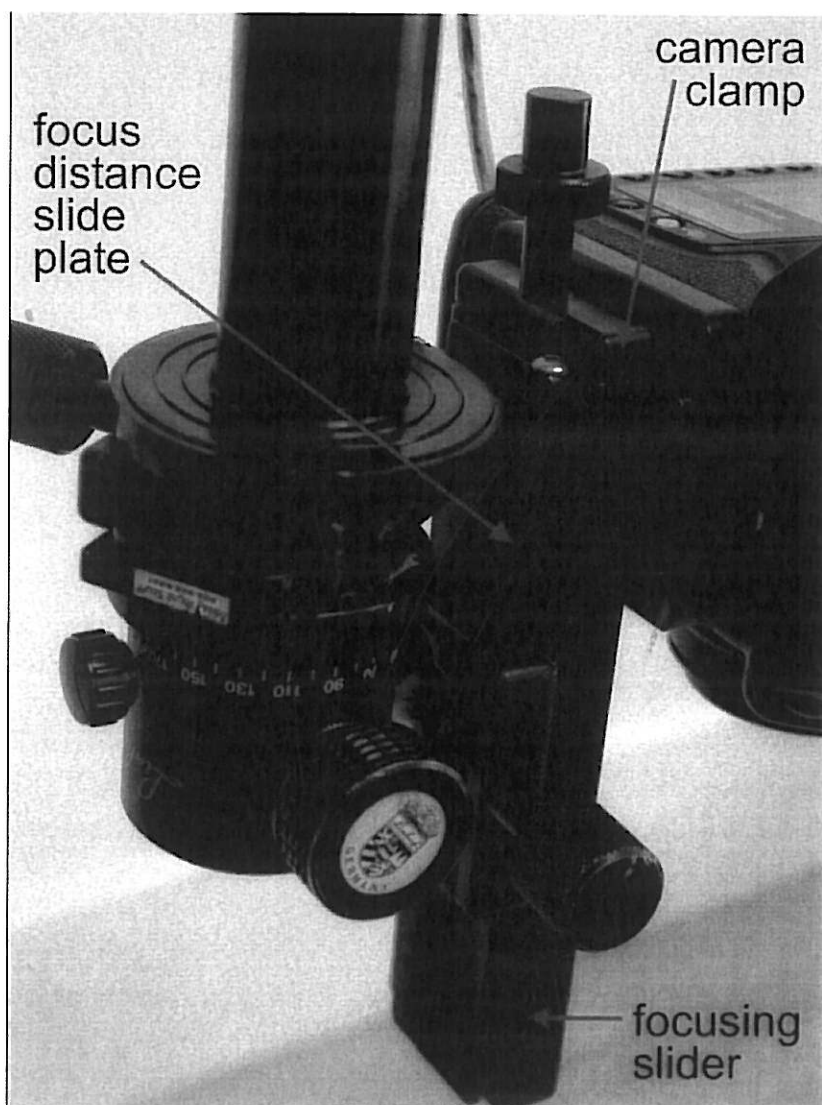
## Camera setup

You must set the digital camera on a tripod for stability; it is very important that there be no movement or vibration of either the camera or subject. You can mount the camera directly on the ballhead (mounted on the top of the tripod or at the bottom of the central post), or on a focusing slider.

There are many possible configurations, depending on the size, portability, and positioning of the target object. Some possibilities are shown in these illustrations.

### Mounting the camera

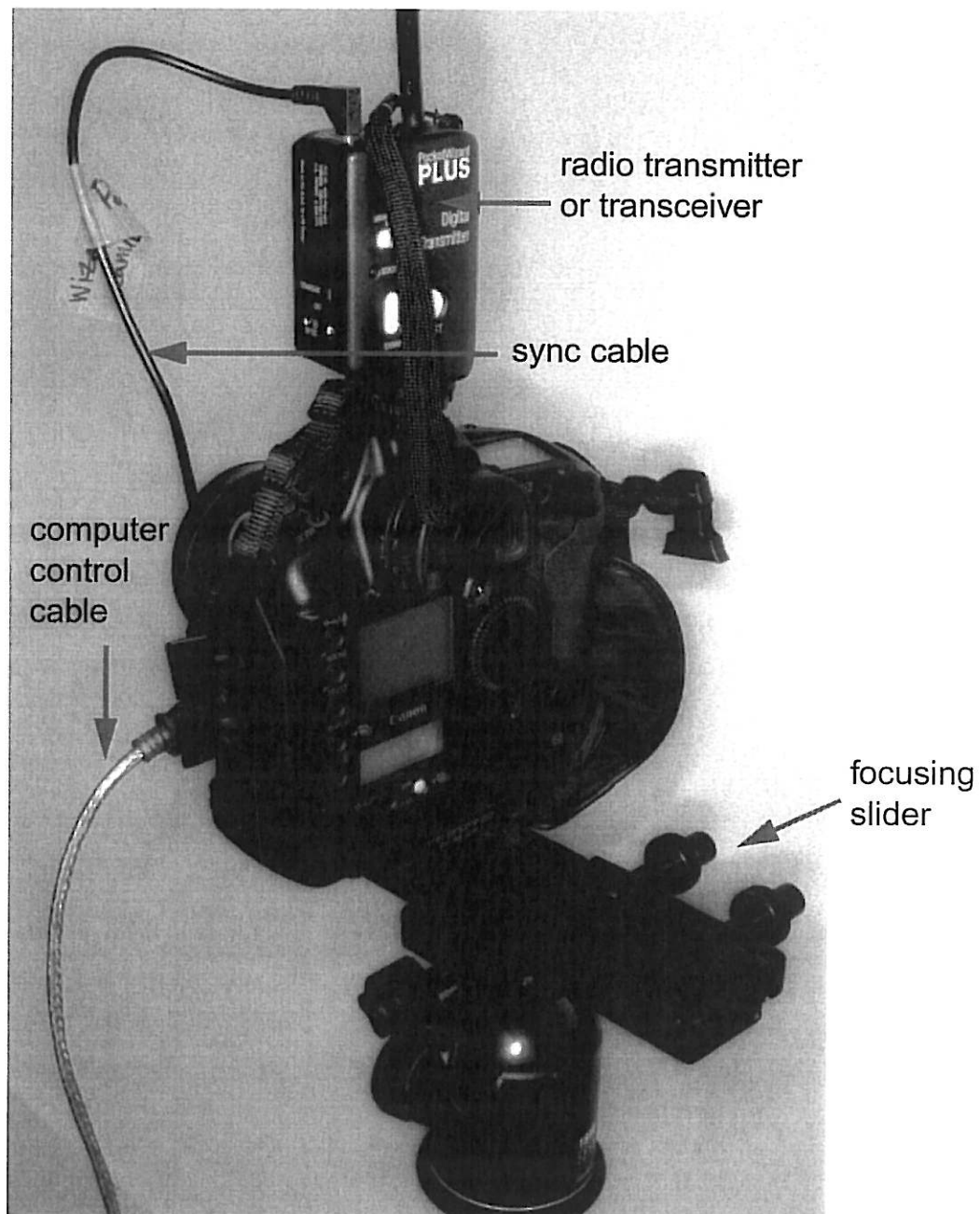
You can mount the camera directly on a ball head on the tripod, or you can mount it on a focusing slider and attach the slider to the tripod's mounting clamp. A slider gives you a further degree of control over the focusing distance, and is especially useful when working with very small objects.



You can attach the camera or camera/slider assembly to a ball head atop the tripod, for a vertical capture position (for paintings hanging on a wall, for instance), or you can attach it or to the lower end of the tripod central column; see ["Choosing a configuration" on page 7](#).

- ▶ Before mounting the camera, attach the lens and any extension tubes you are planning to use.
- ▶ If you are using a slider, attach the camera to the slider before attaching the slider to the tripod or ball head.

Here, the camera is mounted on a focusing slider, which is mounted on the ballhead on top of the tripod. The radio transmitter is optional; see ["Flash lighting options" on page 16](#).



## Choosing a configuration

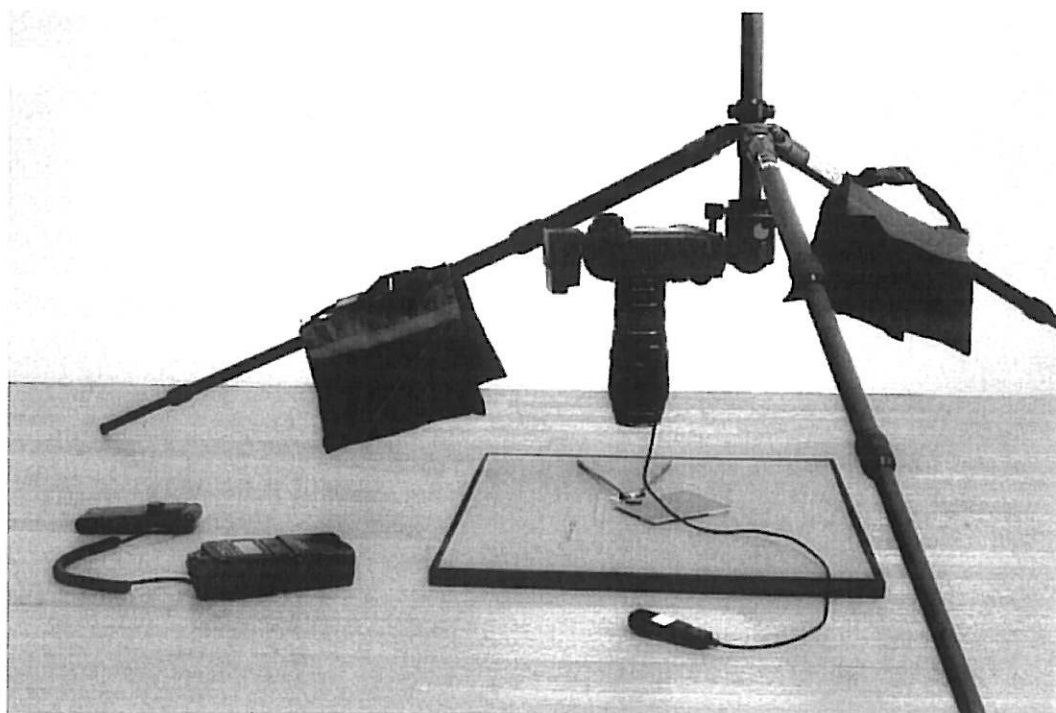
Configuring the camera and tripod depends on the size and portability of the target object. Line up the plane of the camera to be parallel with the plane of the subject or subject detail you wish to photograph.

### Horizontal subject

To shoot a subject that is on a horizontal surface, mount the camera so that it views the subject from directly above.

It is possible to mount a camera on the ball head and rotate the ball 90 degrees so that, when the camera is mounted on the ball head clamp, the lens faces straight down. This only works with very small objects. You must be careful that the tripod legs and their shadows do not obscure the object in the camera's field of view at any lighting angle.

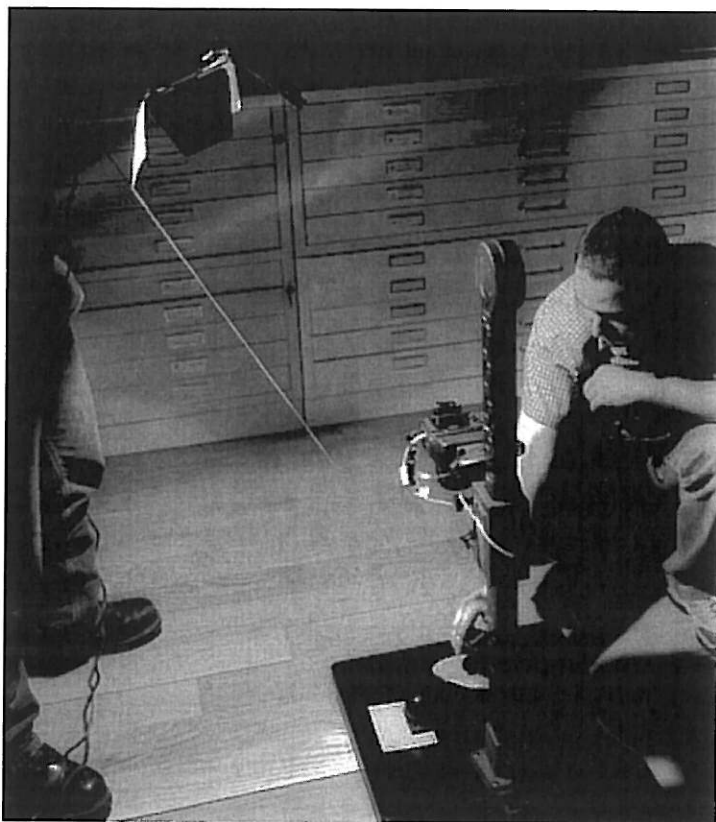
Generally, the best choice for a horizontal subject is to mount a ball head upside down on the bottom of the tripod's central column, and rotate it so that the lens faces straight down. This creates the fewest shadows, and makes positioning easier.



Camera attached to ball head fixed to bottom of central column of tripod, facing down

For larger objects, use a larger tripod. If the subject is too large for available tripods, you may need an alternative camera support, such as a cross bar, supported at both ends, with an attached camera clamp or ball head. The crossbar must be long enough so that the shadows from the cross bar supports are not a problem.





This camera is mounted on a copy stand, facing directly down onto the target object and spheres.

Always choose a configuration and position that minimizes any shadows cast from the tripod legs onto the subject, at any of the lighting angles.

If this is a problem, consider reducing the number of legs that can potentially come between the light and the target, by attaching an extension bar to the bottom of the central column, or suspending the camera from a boom arm. The arrangement must be stable enough to prevent any movement of the camera during the shooting sequence.

If you find that you cannot avoid shadows at some lighting angles, do not shoot at those angles. If you get shadows on areas of interest in any of the images, discard those images during post-processing.

## **Vertical subject**

To shoot a vertical subject, such as rock art or a painting hanging on a wall, mount the camera on a ball head on top of the tripod facing the subject.





## Connecting the computer and lights

When the camera is approximately positioned, set the computer near the camera, and connect the camera to the computer with the USB computer-control cable. You will use the computer to control the camera settings and trigger the shutter and lights, in order to prevent any camera movement.

If you are using a flash, connect the camera to the flash so that it synchronizes the camera's shutter with the flash; see ["Lighting setup" on page 15](#).

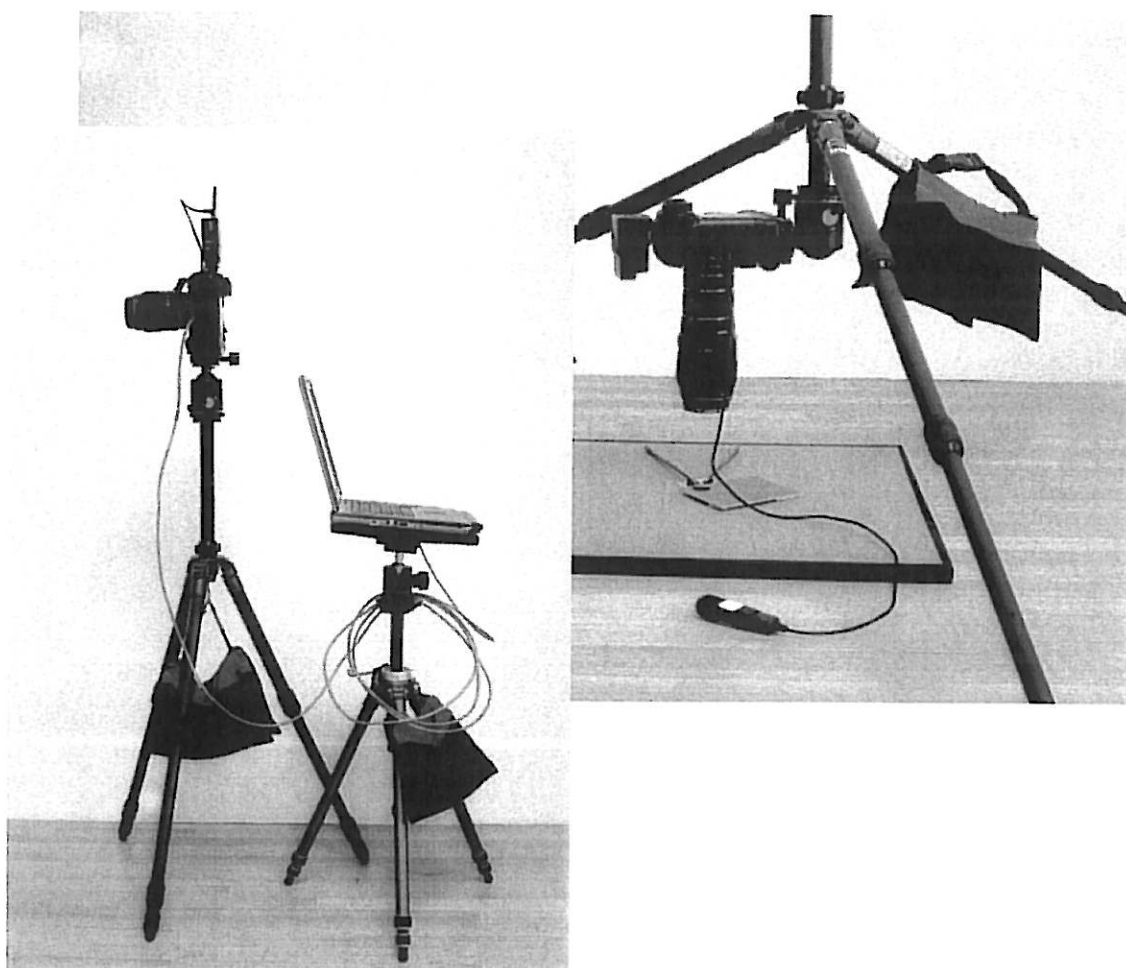
To finalize the camera position, you must adjust the relative positions of camera and subject in order to frame the subject correctly in the camera's view, as discussed in ["Setting up the capture session" on page 21](#).

## Stabilizing the camera assembly

It is essential that the camera not move at all during shooting. Set the tripod legs as widely apart as necessary to prevent shadows, but make every effort to maximize stability. When you have framed the subject correctly in the camera's view, tighten all the clamps and mounting screws. Once everything is correctly framed, you should adjust nothing but the camera focus.

Use weights to stabilize the camera assembly and eliminate all movement and vibration.

- ▶ Drape sand bags over the tripod legs when they are widely separated.
- ▶ If the camera is mounted on top of the tripod, you can hang a weight from a center-column hook inserted in the bottom of the tripod shaft. This is very good for stabilizing the weight of a large camera.
- ▶ You can also use weights around the feet of the tripod, particularly in an outdoor environment.



## Subject and reflective sphere setup

Use a neutral background; colored backgrounds can reflect their color onto the subject. Try to use a white, black, or gray neutral background (as appropriate for contrast with the target object). If the subject is suitable for placement on a flat surface, you can set it on a neutrally colored cloth or surface. Similarly, if it is upright, try to create a neutral background if possible, by hanging it on a neutrally colored wall or setting up a sheet or board behind it.

A *gray card* (18% gray) plays an important role in proper color balancing for the image and its process history; you must include a gray card in at least one image shot during the session. You can shoot it separately from the RTI sequence; see [“White balance” on page 25](#).

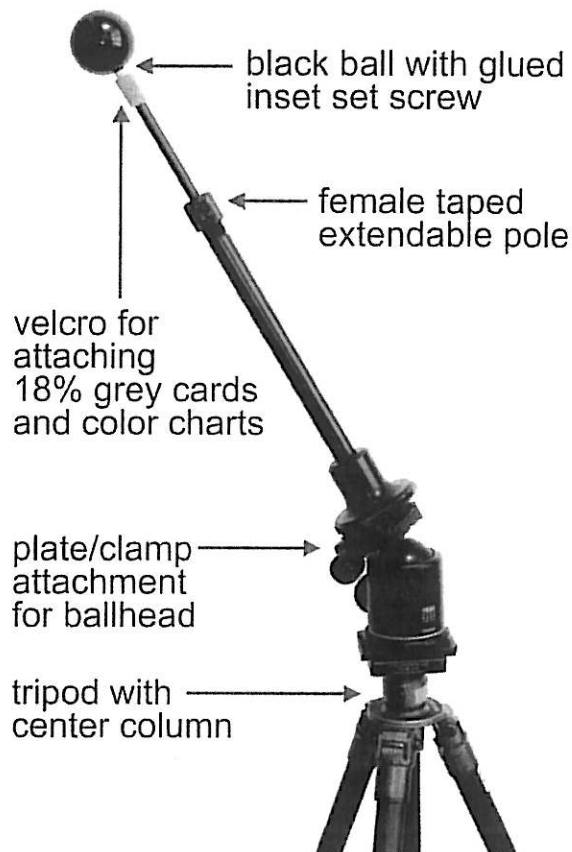
You must set up the target area so that the camera’s field of view contains both the target object and one or two reflective spheres. The reflections of the light source in each image tell the processing software the exact angle of the light for that image. The size and position of the spheres depends on the size and shape of the subject. The diameter of each sphere must be at least 200 pixels in the image.

You will need some or all of this equipment to set up the target area:

- Reflective black spheres in several sizes (such as snooker ball, marble, or ball bearing). You may need to modify the spheres so that they can be attached to holders. See [“Choosing reflective spheres” on page 11](#), and [“Mounting the spheres” on page 12](#).

- ▶ A small piece of 18 percent gray card, placed near the sphere in the image composition. This ensures a proper white balance; it is not needed if the stage itself is 18 percent gray. Place it on the stage near the object, or tape or Velcro it to the sphere stem.
- ▶ For larger spheres, a tripod or light stand, with a ball head and clamp or umbrella clamp light holder, and a boom arm of adjustable length. You must be able to attach a sphere to one end of the arm or rod, and attach the other end to the light stand or tripod.

### Extendable Black Ball on Tripod



### Choosing reflective spheres

The size of the sphere you use depends on the size of the subject. The sphere diameter in an image must be at least 200 pixels wide. If your sphere is too large, however, it takes up more of the image area than is necessary, reducing the number of pixels devoted to the subject.

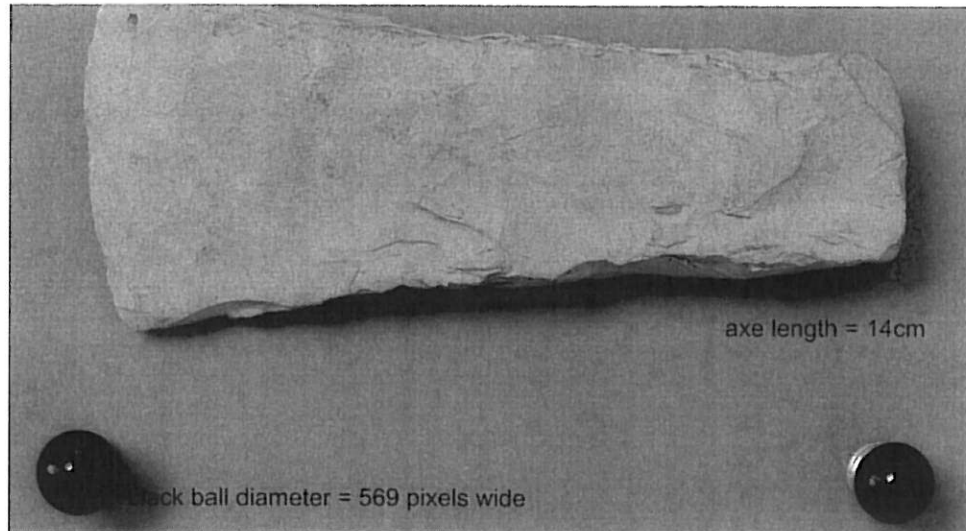
For small objects, you might use a marble or ball bearing. For larger objects, you can use a snooker billiard ball or larger sphere.

The sphere should be black; you can darken light-colored spheres or marbles with black dye or ink. This works best with spheres already mounted on holders. Take the holder (such as a chop stick) and dip the end with the sphere into the dye or ink; then set the end you are holding into a block of foam or a flower pot so that the excess ink can flow down the holder, leaving an evenly coated sphere on top.

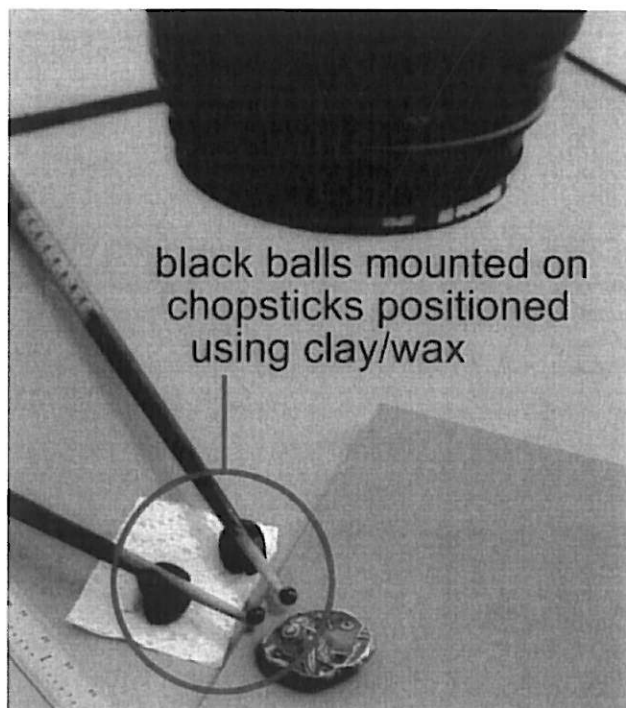
## Mounting the spheres

The way in which you mount the black sphere depends on its size and where it must be positioned to be near the subject. There are two general ways to mount them; you can set them on a small, stable stand near the subject, or you can extend them into the camera's field of view on a pole or rod.

- ▶ You can place marbles and ball bearings on washers, brass studs, or other small discs to support them during the capture sequence.



- ▶ You can glue marbles and ball bearings directly to small sticks or rods (such as chopsticks or skewers), and mount these to clamps on tripods or other structures.

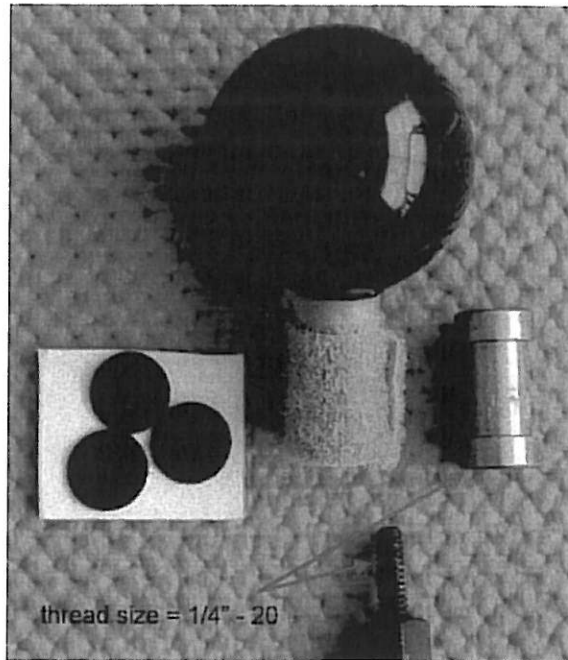


For this small object, we used ball bearings colored black with dye, and glued them to the ends of chopsticks.

We then placed the chopsticks on clay stands to hold them securely in the chosen position:

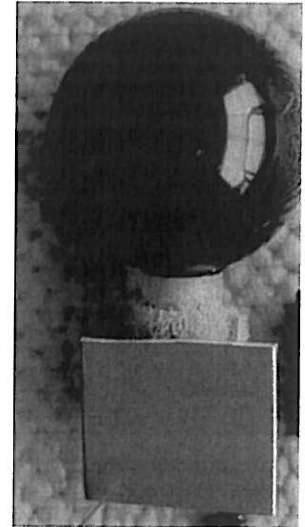
- ▶ Close to the subject, but where they can be cropped out of the image
- ▶ Not shadowing the subject from any lighting angle

- You can drill into larger spheres to insert and glue set screws or small metal rods, which you can then attach to extendable booms, mounting plates, and other structures.



Epoxy holds a set screw in place, allowing this sphere to be screwed into a brass fitting and attached to an extendable arm or rod.

Use Velcro to attach a bit of gray card to the post, to ensure a good white balance if the background is not gray.



For a very inexpensive rod that can be easily attached to the sphere, you can use 3/8 or 1/4 inch *threaded stock*, found in most hardware stores.

A good choice for attaching a rod to a light stand is an inexpensive *umbrella clamp*, found in photography supply stores. Attach the threaded rod to one end of the umbrella clamp, and attach the other end of the clamp to the light stand or other positioning device.

This elbow is an umbrella clamp for a light stand. You can insert a simple threaded rod into this and into the sphere to make a boom arm for holding the sphere in position.



## Placing the spheres

As with the various camera setups, you must adjust the sphere configuration according to the circumstances of the subject and environment. Look through the camera lens to determine a suitable position for the spheres.

During post-processing, you will crop out the reflective spheres from the images; this is something to keep in mind when positioning them. They must be close enough to the subject so that the camera can focus on both the spheres and the subject with sufficient depth of field, but far enough so that you can crop them out of the image without losing any image data for the subject itself.

If you use a light stand and extending pole to support a black sphere in the camera frame:

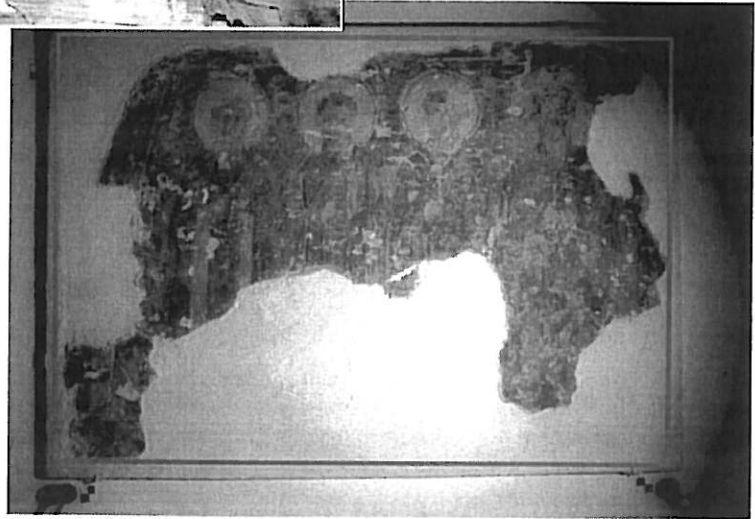
- ▶ Adjust the stand's legs to make it stable. As with the camera, it is important that the spheres not move at all while you are capturing the images.
- ▶ You can slide the extendible pole's mounting plate into the stand's ball head clamp, or if there is no mounting plate, insert it into the top half of the umbrella clamp.
- ▶ Attach the black sphere and a gray card sample onto the far end of the extendible pole.
- ▶ Position the entire assembly so that the black sphere extends into the desired area of the image composition, close to the photographic subject.
  - ▷ Looking at the camera's view, position the sphere in a corner of the shot, where it can be cropped out without losing any of the object data. Keep in mind that cropping requires you to specify a rectangular area around the object.
  - ▷ Consider how the shadows of the spheres will fall on your object with the light source at different angles, and try to minimize these shadows.
- ▶ After adjusting the angles of all the components, tighten all the clamps or mounting screws to stabilize the setup, and add weight to the light stand to increase stability.



These crop rectangles show how the reflective spheres are cropped out of the captured images.

The black spheres in the lower corners are supported on adjustable arms in these configurations, where the subject is vertical.

Notice the shadows cast by the spheres and arms, which do not fall on any areas of interest in the subject itself.



## Lighting setup

In order to build an RTI using the highlight method, you move the light source to an approximate position in a flexible sampling pattern before each shot, to create a hemispherical set of lighting samples around your photographic subject. The lighting samples cover a range of inclination angles from 15 degrees above the horizon to 65 degrees above the horizon, and an even sampling around the subject, all at a fixed distance from the subject (which you can measure simply with a string). For more about the specific angles, see ["Capture sequence"](#) on page 24.

To do this, you must have a portable light source. The light should generally be on an extendable arm; especially for larger objects, you will have to position it higher than you can reach for some of the shots.

The type and intensity of the lighting you need varies according to whether you are photographing indoors or out, and the size of the target object. Indoors, you can plug the light into the wall or a power strip. In the field, you can use a battery pack or a generator.

There are two basic light source types; continuous lights, and flash or strobe lights. Each type has its own advantages and disadvantages:



- ▶ Continuous lights can be aimed quickly and accurately at the center of the subject, permit longer exposures if more light is required, and do not need to be synchronized to the camera shutter.

Continuous light is easy to work with if you are indoors and have appropriate power. It doesn't work well in location settings where you might not have a generator and can run out of batteries. You have to manage a power cord (although this is also required with the larger studio flashes).

- ▶ Flash units can produce a very bright flash that can be needed in high ambient-light environments, such as outdoors in daylight, or for shooting large objects. They use less electricity than similarly-powered continuous lights, which can be important when working on location away from the power grid.

The most portable option with the fewest cords is a camera-mountable flash unit with an infrared trigger, and a battery pack attached to the flash unit. This is suitable for subjects less than a meter in diameter.

## Lighting equipment

You will need some or all of this equipment to set up your lighting assembly:

- ▶ A lighting unit, with a battery pack or AC cord.
  - ▷ For flash lighting, a triggering system. This can be a wireless transmitter and receiver for radio flash triggering, an infrared trigger for a remote camera flash, or a sync cable directly connecting the flash unit to the camera. See ["Flash lighting options"](#) below.
- ▶ A UV filter for the light, if the subject requires it.
- ▶ An adjustable monopod pole light stand.
- ▶ A piece of string, rope, or cord approximately 4 times the diameter of the object or object detail you wish to image. You will use this to maintain the correct distance from the light to the subject for each shot; see ["Setting up light-to-subject distance"](#) on page 22.

## Flash lighting options

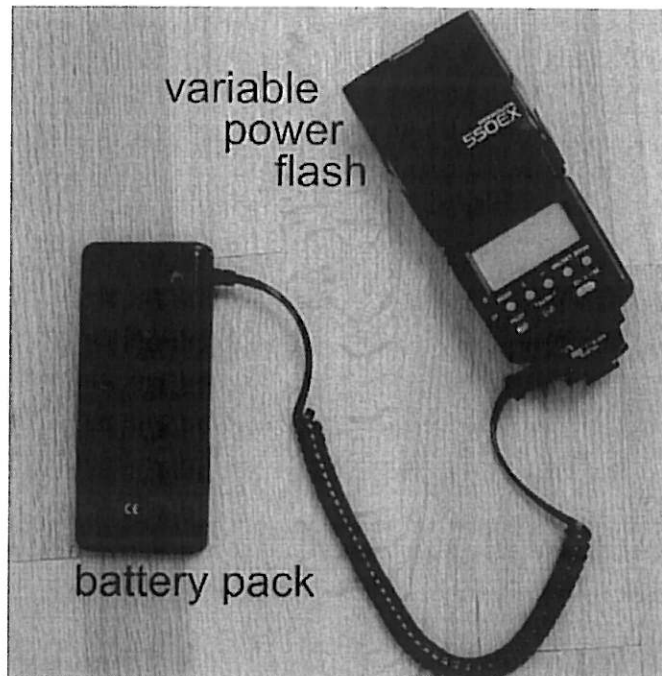
If you use a flash or strobe, you must connect it to the camera so that it flashes when the shutter is open capturing each image. (You will be triggering the camera remotely; see ["Triggering trade-offs"](#) on page 25). The easiest way to do this is to attach the light directly to the camera with a sync cable. Alternatively, you can use a wireless transmitter for radio flash triggering, attached to the light by a sync cable; for example, a PocketWizard wireless transmitter and receiver. This works well with a studio light, such as AlienBees B1600 with a 100-watt modeling lamp and a 5600° K daylight-balanced flash tube light.

The sync cable is cheaper than a radio trigger, and you might want to have it as a backup, even if you use a radio trigger. However, it adds an extra cable to keep track of as you move the light into its capture positions. A sync cable should be at least 50 feet in length. You must be very careful to secure the end of the cable near the camera, using tape or weights for example, so that movement in the cable is not transferred to the camera. Any movement will ruin the entire sequence.

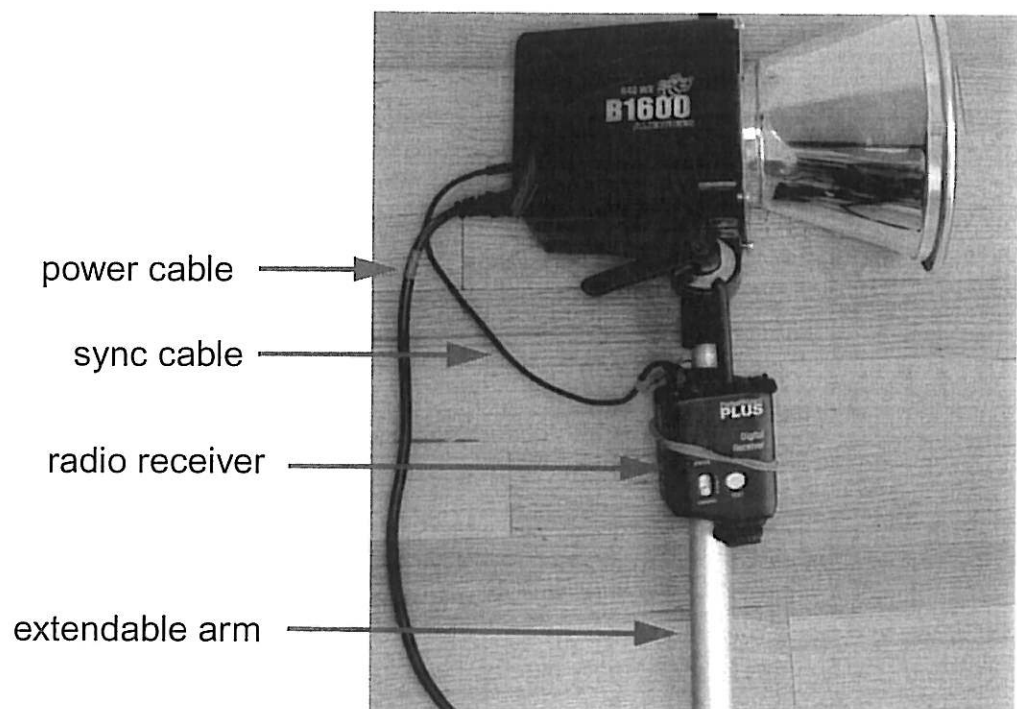
You can also use a radio trigger with a camera flash that would normally work from the camera's hotshoe; however, these typically use a simpler infrared trigger, which is cheaper than a pair of radio triggers and can be used in other kinds of photography to fire more than one flash. If you are using a flash or strobe unit:

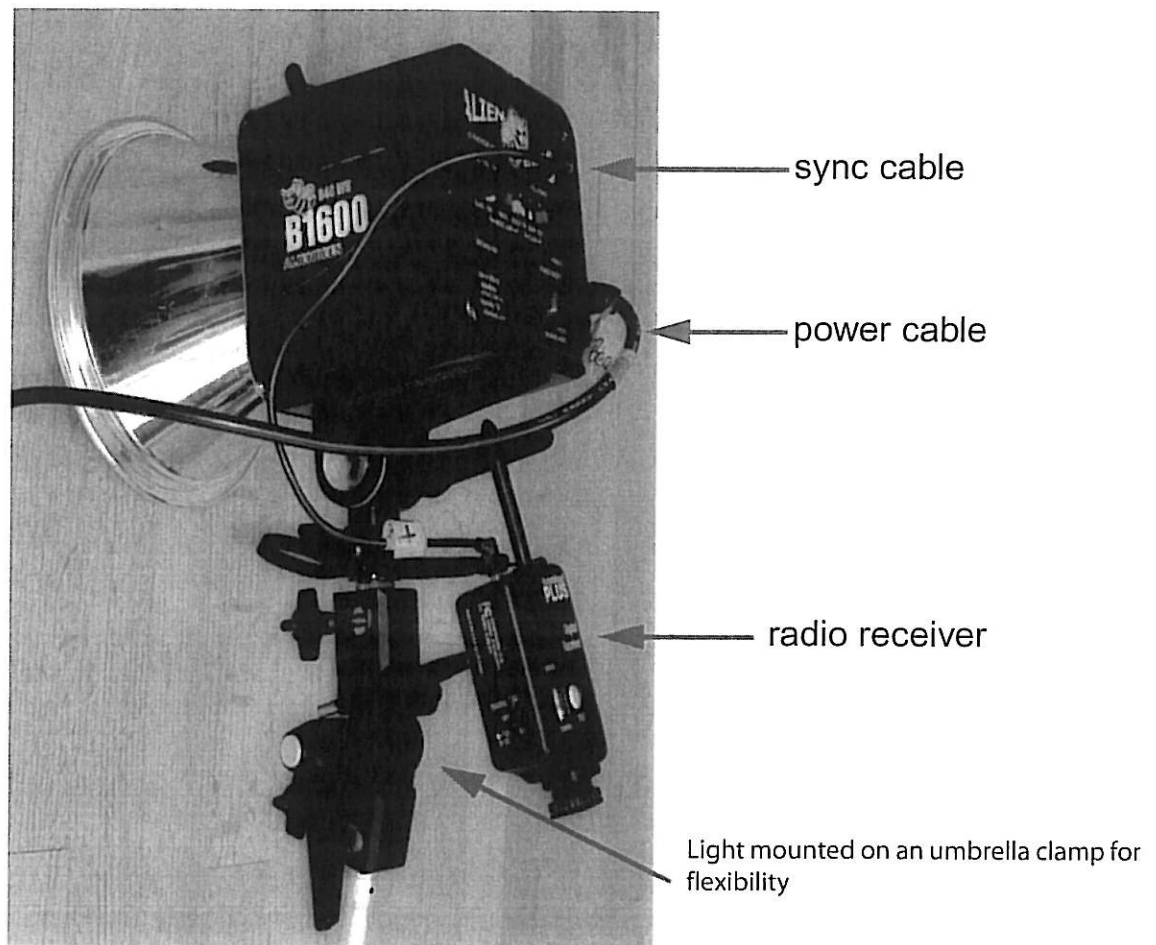
1. Attach the infrared trigger unit to the hot shoe of the camera.

2. There are four channels available; use the same channel for the STE-2 and for the Canon flash unit.
3. Set the flash to Manual mode and dial in the flash exposure that you establish with a test shoot.



Whichever system you choose, attach the lighting unit and transmitter or sync cable to the monopod; some options are shown here. When you have connected the power pack to the camera by whatever system you have decided on, you should test the flash.

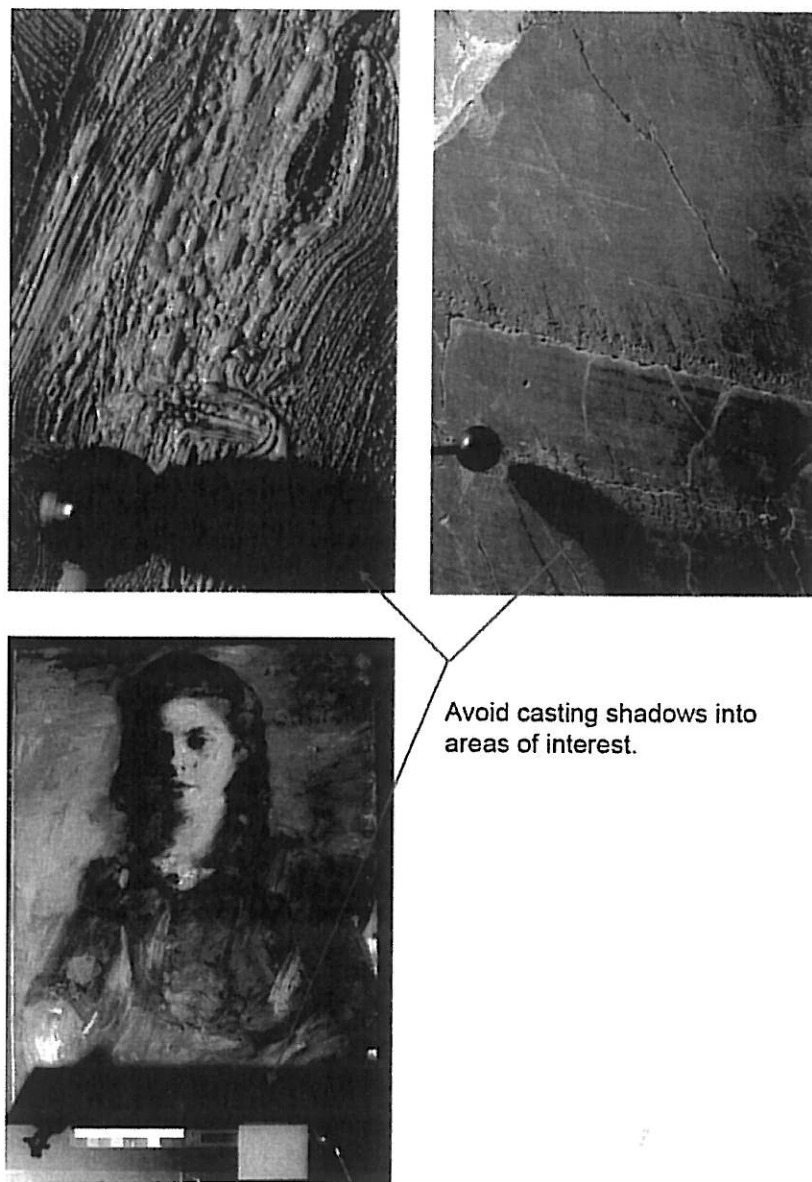




## Testing the light model for shadows

Light stands, tripods, cables, and other tools and equipment can cast shadows on your subject while photographing it. Try to minimize the effects of shadowing by positioning your subject carefully.

When you have set up and tested the lighting unit, you can test for shadows. Turn on the lamp and move the light around the subject, looking for angles and distances that create excessive shadowing on the subject. Rearrange the target or camera placement to eliminate these shadows, if possible. If you cannot eliminate them, note these light locations and avoid using them during the image capture and testing sequences.



## Computer software setup

We recommend that you create a capture folder that contains all of the relevant tools, or shortcuts to them. You will need to install these applications:

- The camera control application for your camera (such as the Canon EOS Utility), used to adjust camera settings and to set the image storage location.

Use to set up the focus, exposure, and depth-of-field of the cameras. The LiveView feature allows you to do this without taking test shots; the image you see on the screen is the same as the image on the camera's LCD, and shows the effects of settings in real time. See ["Performing Highlight Image Capture"](#) on page 21.

- ▶ Adobe Bridge CS2 or later, or Adobe Lightroom, used to stamp image files with metadata and keywords.
- ▶ Adobe Digital Negative Converter (DNG), used to process camera-raw image files and make copies in the JPEG format, is part of Adobe Photoshop and Adobe Lightroom. You can download it separately if you need updates that support a newer camera. Download from:  
<http://www.adobe.com/support/downloads/detail.jsp?ftpID=3822>

For more information on how to use these tools, see *“Performing Highlight Image Capture”* on page 21.

The following tools are needed for post-processing. They do not need to be installed for image capture, and do not necessarily need to be installed on the same computer.

- ▶ RTI Builder, used to process images to produce RTIs.
- ▶ PTM or RTI Viewer, used to view the result.

For more information on how to use these tools, see *Processing Highlight Image Data*.

# Performing Highlight Image Capture

You should establish a naming convention for the folders in which initial images are stored, and for the filenames of the captured images. Choose names that unambiguously identify the subject and circumstances. For the image name template, specify a filename postfix of an underscore and a 3-digit serial number.

## Setting up the capture session

1. Make sure the camera is connected to the computer with the USB cable
2. Turn both the camera and the computer on.
3. Check that the camera battery is fully charged, or use an AC adapter plugged into a power outlet.
4. Start the camera control application.
5. Create a folder in which to store the initial images, named according to your own naming convention. In the EOS Utility, use the Preferences dialog to specify this folder as the storage location for the session. Set the filename template here as well.
6. Set the camera to never turn itself off.
7. Determine and mark the optimal subject-to-light distance on the string; see [“Setting up light-to-subject distance” on page 22](#).
8. Use autofocus to get an approximate focus, then switch the camera to Manual mode, so that it does not automatically choose a shutter speed or aperture.

For larger objects that are farther away, the result of autofocus may be good enough. For smaller objects, especially when using extension tubes for closer work, you will probably need to refine the focus manually. In any case, the focus must be set to Manual before you actually begin image capture.

9. Use the Settings window to control the camera settings for focus and exposure; see [“Shutter and aperture settings”](#) below.
  - ▷ If you have Live View and are using constant lighting, you can use Live View to determine the correct settings. Otherwise, take test shots and examine the result in order to adjust the settings. See [“Triggering trade-offs” on page 25](#).
  - ▷ Set the camera to capture JPG Large for test shots.
10. Always switch the lens to Manual mode, so that it does not automatically refocus. You have to do this with the physical switch on the lens; be very careful not to move the camera at all.
11. Set the camera to capture RAW files for the capture sequence.

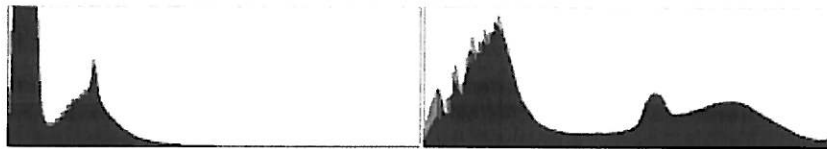
## Shutter and aperture settings

To focus the camera correctly, you need to set the combination of light intensity, shutter speed, and aperture. Your goal is to have every element of the subject and the front half of the black spheres in focus

and visible, and to collect as much light as possible while avoiding under-exposure and over-exposure at the extremes

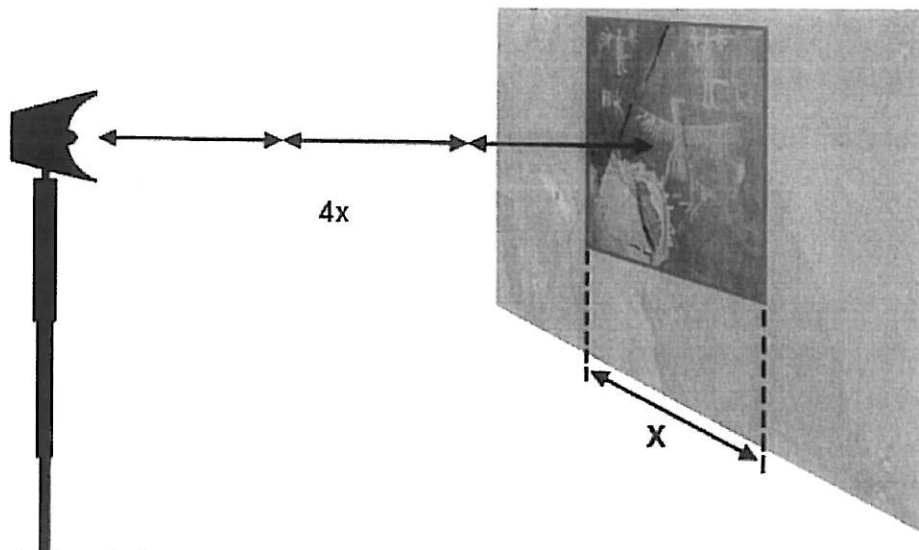
- ▶ Do not use apertures narrower than  $f/13$  -  $f/16$ . Smaller apertures can result in degradation of the digital image. The overall depth of field is increased, but you lose sharpness. A good target aperture is between  $f/5.6$  and  $f/11$ , if possible.
- ▶ Check the histograms for the lightest and the darkest images, and make sure that no whites are blown out, and no shadows are too dark. The lightest image is the one taken with the light nearest the zenith (at 65 degrees inclination), and the darkest is the one taken with the light nearest the horizon (at 15 degrees inclination).

These histograms, for example, show how the entire usable exposure range is bracketed by the extremes of inclination. The histogram on the left shows the darkest image, where the black end of the range predominates. The one on the right shows the lightest image, in which there is a good spread of color usage all the way to the white side, but very few all-white pixels. A spike at the white end would indicate blown-out portions of the image due to over-exposure.



## Setting up light-to-subject distance

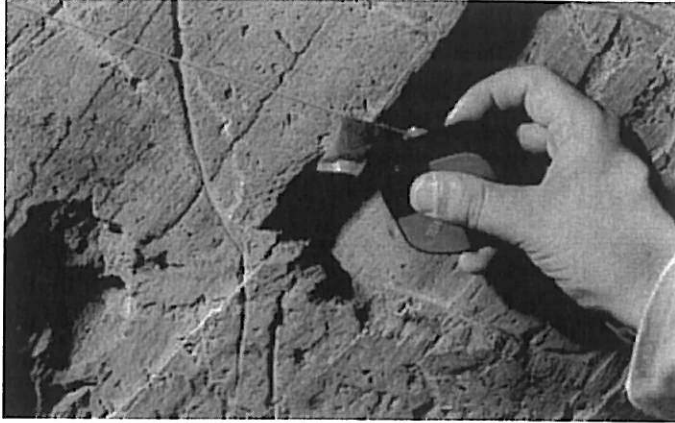
The minimum recommended distance from the light to the subject is four times the diameter of the subject. If it is impossible to set the object at this distance, try to set it as far away from the light as possible.



Many high-tech distance measuring methods have been evaluated, including lasers and image processing methods determining light intensity. A string (affectionately called 'the Egyptian Method') has proved to be the most efficient. If you are using a string or rope, tie it onto the light stand below the flash unit. A good choice for field work is a surveyor's plumb line, with the plumb bob removed.

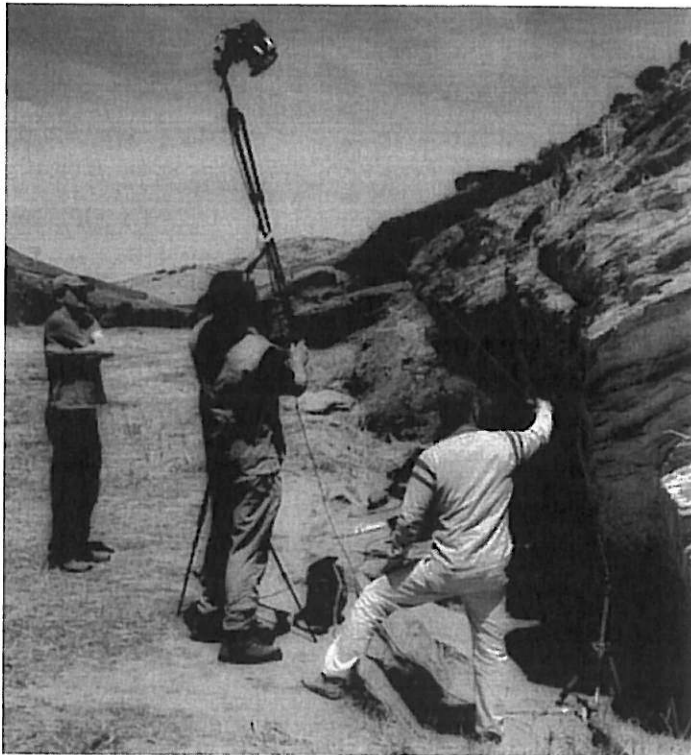


During your test shots, when you are setting the focus and depth of field, extend the string to an area about 6 inches above the center of photographic subject, and mark the distance. You can tie a knot in a small string, for instance.



You typically need one person to hold the string end at the correct location by the subject, while another person positions the light at the correct distance and angle for each shot. For small objects, where the string length is only a few feet, one person can hold both the string and the light.

- Make sure to move the string out of the shot before capturing the image.



## Capture sequence

To create an image sequence, you must take at least one shot with the light source at each position in an imaginary light dome around the object. Imagine that the dome is like an umbrella, in which each rib extends from the center of the camera lens (the top of the umbrella) out to points surrounding the subject like the numbers on a clock face. There should be 8 to 12 ribs; along each rib, there should be 3-6 inclination points, depending on the desired quality (see ["Quality tradeoffs" on page 25](#)). The ribs and inclination points should be at approximately equal distances from one another.

Considering the camera to be at 90 degrees from the subject, and the plane of the subject 0 degrees, the lighting angles should be between 15 and 65 degrees.

1. Check your settings in the camera software to ensure that the values you chose during your test shots are still active.
2. Brush dust, hair, and fiber out of the shot before capturing images.
3. Begin with the light at the 12 o'clock position (that is, along the first rib of the imaginary dome), and 15 degrees above the plane of the subject. Move the light to the correct distance as shown by the string. Position the light so that the center of the cone of light points directly at the subject and remains parallel to the string. When the position is established, move the string out of the shot.
4. To take the shot, trigger the camera from the computer, using the EOS Utility application or a timer device (see ["Triggering trade-offs" on page 25](#)).
5. Move the light to the next inclination point along the 12 o'clock rib of the imaginary dome.
6. Use the string to ensure that the light is the same distance from the subject, and adjust if necessary. Do not let any part of the string brush against your subject as you are capturing images. Any movement of the subject during image capture affects image quality. Every time, make sure the string is out of the shot.
7. Wait several seconds after moving before you take the next shot; this reduces any vibration or movement. Hold the light as steady as possible before and during the shot. Take care not to brush the camera tripod or sphere mounts. (This helps protect the subject, as well as ensuring accurate images.)
8. Continue moving the light and taking shots through all ribs and inclination points, to create a collection of 24 to 72 images. You can take fewer shots and still get good results; more shots provide greater quality in the resulting RTI. See ["Quality tradeoffs" on page 25](#).

You can get usable data even for objects that are partially blocked. If you can't get far enough away with the light in some positions, you can skip those positions. In the viewer, you will not be able to see the light change in the direction you have not shot, but other directions still work correctly, and a usable normal field, suitable for mathematical enhancement, is created.

If you accidentally shoot the string or a hand, you don't need to start over; you can discard that image later. Simply take another shot from the same lighting angle. Similarly, you can discard images if you overshoot, or get too close to the horizon, or too close to the camera. The only reason to start over is if something moved.

If any element moves (a sphere, the camera or the object), you must start over, unless you already have enough images for a usable data set. If you are not sure there was movement, make a note or take a picture of your hand to mark the point at which you think movement occurred, and continue with the rest of the sequence. You must then check the image sequence to see if movement did occur at the suspected point, and if it did, discard the sequence.

## White balance

After you have established the lighting distance, take one shot of a standard photographic 18% gray card, to establish the correct color balance. You will use this in post-processing to correct the white balance of the entire image sequence.

If you have attached the gray card to the reflective spheres (as shown in [“Mounting the spheres” on page 12](#)), you do not need to take separate shots. Otherwise, you can include the gray card in one of the image sequence shots, or shoot the gray card before or after capturing the image sequence.

## Triggering trade-offs

You must trigger the camera remotely, to avoid movement, but you can use either the camera-control software on the computer, or a remote trigger for the camera.

We highly recommend shooting from the computer so that you can look at your test shots, get the focus right, and so on. Files are named automatically, and when you are done, all the data is on the computer in a standard location.

If you choose to shoot an RTI sequence using a remote trigger, you should take test shots and look at the histogram on the camera. For larger objects, you can often get a good enough focus using autofocus, then switch the lens to manual for the actual image sequence. For small objects, you generally need to take more test shots and make fine adjustments to get the correct focus and depth of field.

When you have finished taking test shots, shoot your hand or some other indicator, to provide an obvious visual cue for where the test images end and the session image sequence begins. This will make it much easier to sort out the images later. We have used a film clapper with a grease pencil to note this information, but anything will do.

## Quality tradeoffs

The more images you capture, the higher the quality of the resulting RTI; that is, more input data allows the processing software to calculate more accurate normals and develop a better model for the surface topography of the object.

For interpretive purposes in a RTI viewer, this doesn't make too much difference, but if you want to use the data in subsequent algorithms, such as converting to 3D, or measurement, you need more accurate normals.

The normals are accurate relative to each other, even with a small sample size. The absolute accuracy, however, with respect to an input image with light from a particular angle, is less accurate with a smaller sample size. A large sample size means not just a greater number of images, but a greater sample of light directions around the hemisphere.

## Post-processing

When you have finished acquiring the original images from the capture sequence, you must perform a set of post-processing operations to combine these images and ancillary data into the final RTI image file.

- You need to review the captured images for usability, add identifying metadata to each one, and convert it from camera-raw to JPEG format.

- ▶ You use a utility application to collect the ancillary data on the exact light positioning for each image, which is computed from the highlights on the reflective spheres.
- ▶ When this is done, you must crop out the reflective spheres from the images.
- ▶ Finally, you collect the processed image files and light-position data files into a single folder, and run the script that generates the final PTM or RTI file.

This subject is discussed in separate document, *Processing Highlight Image Data*.